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Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River near Eagle, Alaska, 2012

by

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and

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

ALASKA

DEPARTMENT OF FISH AND GAME

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Dual frequency identification sonar and split-beam sonar equipment were used to estimate Chinook salmon *Oncorhynchus tshawytscha* and fall chum salmon *Oncorhynchus keta* passage in the Yukon River near Eagle, Alaska from July 4 to October 6, 2012. A total of 34,747 Chinook salmon were estimated to have passed the sonar site between July 4 and August 19. The midpoint of the Chinook salmon run occurred on July 29, which was 4 d late relative to the historical mean date of July 25. An estimated 147,710 chum salmon passed between August 20 and October 6. The sonar-estimated passage of chum salmon was subsequently expanded to a total passage estimate of 153,248 to include fish that may have passed after operations ceased. The midpoint of the chum salmon run, with and without the expansion, occurred on September 22, which was equivalent to the historical mean date of September 22. An estimated border passage of 34,656 Chinook salmon and 141,648 chum salmon was calculated by subtracting the preliminary subsistence catch from upstream of the sonar site. A drift gillnet sample fishery was conducted to collect age, sex, length, and genetic information. Species composition was recorded to determine when the Chinook salmon run ended and the fall chum salmon run began. Both sonar systems functioned well with minimal interruptions to operation. The range of ensonification was considered adequate for most fish that migrated upstream. A continued long-term hydroacoustic enumeration project for Chinook and chum salmon near the United States/Canada border will help fishery managers meet conservation and management commitments made by both countries under the Yukon River Salmon Agreement.

Key words: Alaska, Yukon River, Eagle, Chinook salmon *Oncorhynchus tshawytscha*, chum salmon, *Oncorhynchus keta*, dual frequency identification sonar DIDSON, split-beam sonar, hydroacoustics.

INTRODUCTION

The Yukon River is the largest river in Alaska, spanning 3,700 km. It flows northwest from its origin in northwestern British Columbia through the Yukon Territory and Central Alaska to its mouth at the Bering Sea. Commercial and subsistence fisheries harvest Pacific salmon *Oncorhynchus* spp. throughout most of the drainage. These fisheries are critical to the way of life and economy of people in dozens of communities along the river, often providing the largest single source of food or income. Fisheries management on the Yukon River is complex and difficult because of the number, diversity, and geographic range of fish stocks and user groups. Information upon which to base management decisions comes from several sources, each of which has unique strengths and weaknesses. Gillnet test fisheries provide inseason indices of run strength, but interpretation of these data are confounded by gillnet selectivity and the functional relationship between test fishery catches and abundance are poorly defined. Mark–recapture projects can provide estimates of total abundance but are not timely enough to make day-to-day management decisions. Sonar projects can provide timely estimates of abundance but are limited in their ability to identify fish species.

Alaska is obligated to manage Yukon River salmon stocks according to precautionary, abundance-based harvest-sharing principles set by the *Yukon River Salmon Agreement* (Yukon River Panel 2004). The goals of bilateral, coordinated management of Chinook *O. tshawytscha* and chum *O. keta* salmon stocks are to meet negotiated escapement goals and to provide for subsistence and commercial harvests of surplus in both the United States and Canada. Timely estimates of abundance help managers adjust harvest inseason and are crucial for postseason analysis to determine whether treaty obligations were met. The Canadian Department of Fisheries and Oceans (DFO) provided estimates of mainstem salmon passage through the U.S./Canada border using mark–recapture techniques from 1980 to 2008.

Because of the highly turbid water of the Yukon River, and the width of the mainstem (approximately 400 m across at the study site), daily passage estimation methods that rely on visual observation, such as counting towers and weirs, are not feasible. Split-beam sonar technology has been used successfully by the Alaska Department of Fish and Game (ADF&G) to produce daily inseason estimates of salmon passage in turbid rivers, including the lower Yukon River at Pilot Station (Carroll and McIntosh 2008) and the Kenai River (Miller and Burwen 2010). Dual frequency identification sonar (DIDSON)[1] has been used at several sites, including the Aniak River (McEwen 2010) and Sheenjek River (Dunbar 2010) to give daily passage estimates where bottom profile and river width are appropriate for the wider beam angle and the shorter range of this technology.

In 1992, ADF&G initiated a project near Eagle, Alaska (Figure 1) to examine the feasibility of using split-beam sonar to estimate the number of salmon migrating across the U.S./Canada border (Johnston et al. 1993; Huttunen and Skvorc 1994). This project was the first documented use of split-beam sonar in a riverine environment and, over the 3 years of study, a number of problems were identified. Phase corruption was observed and was probably exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds causing the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed.

A recommendation that came out of these studies was to find a more appropriate site with smaller rocks and a uniform bottom profile (Johnston et al. 1993). Too many large rocks or obstructions in the profile can compromise fish detection by limiting how close to the bottom the hydroacoustic beam can be aimed. Similarly, an uneven bottom profile permits fish to pass undetected by the sonar.

In 2003, ADF&G carried out a study to identify a more suitable location to deploy hydroacoustic equipment to estimate salmon passage into Canada. A 45 km section of river from the DFO mark–recapture fish wheel project at White Rock, Yukon Territory to 19 km downriver from Eagle, Alaska was explored (Pfisterer and Huttunen 2004). This area was investigated because of its proximity to the DFO project and the U.S./Canada border. Desirable characteristics included: steady downward sloping linear bottom profiles on both sides of the river without large obstructions; a single channel; available beach above water level for topside equipment; and sufficient current, (i.e., areas without eddies or slack water where fish milling behavior can occur). A total of 21 river bottom profiling transects led to potential project locations located between 9 km and 19 km downriver from the town of Eagle. The 2003 study identified Calico Bluff and Shade Creek as the most promising sonar deployment sites. Though sonar was not deployed in 2003, the bottom profiles at the preferred sites indicated that it should be possible to estimate fish passage with a combination of split-beam sonar on the longer, linear left bank and DIDSON on the shorter, steeper right bank. In 2004, ADF&G operated test sonars at the preferred sites over the course of 2 weeks. Both types of sonar were tested each site and it was found that Six Mile Bend (11.5 km downriver from the town of Eagle and immediately upstream of Shade Creek) was the ideal site (Carroll et al. 2007a).

In 2005, a full-scale sonar project was conducted from July 1 to August 13 to estimate Chinook salmon passage in the Yukon River at Six Mile Bend (Carroll et al. 2007b). As suggested, DIDSON was deployed on the right bank and split-beam sonar was deployed on the left bank.

[1] Product brand names are included in this report for scientific completeness, but do not constitute product endorsement.

The project duration was extended in 2006 to provide an estimate of fall chum salmon passage. Split-beam and DIDSON technology have since been used in subsequent years to estimate border passage for both Chinook and fall chum salmon.

In 2013, the project deployed split-beam and DIDSON sonar to estimate Chinook and fall chum salmon passage migrating across the U.S./Canada border. Sample fisheries were conducted to determine the transition between Chinook and fall chum salmon runs as well as collect age, sex, and length (ASL) and tissue samples for stock identification. This report will describe in detail the methodologies used to collect sonar and test fish data and will provide passage estimates, species distributions, run timing, and climate and hydrologic observations.

OBJECTIVES

The primary goals of this project in 2012 were as follows:

1. Estimate the daily passage, seasonal passage, and run timing of Chinook and fall chum salmon using fixed-location split-beam and DIDSON sonar.
2. Use drift gillnets to estimate the end of Chinook salmon run and the beginning of the fall chum salmon run past the sonar site.
3. Collect a minimum of 160 Chinook salmon scale samples during each of 3 strata throughout the season to characterize the ASL composition of Yukon River Chinook salmon passage such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
4. Collect a minimum of 160 fall chum salmon scale samples during each of 4 strata throughout the season to characterize the ASL composition of Yukon River fall chum salmon passage such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
5. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
6. Collect daily climatic and hydrologic measurements representative of the study area.

METHODS

STUDY AREA

The study area is a 2 km section of the mainstem Yukon River at Six Mile Bend, 11.5 km downriver from Eagle, Alaska (Figure 2). Additional drift gillnet fishing occurs about 5 km farther downriver near Calico Bluff.

The Yukon River Basin is the fourth largest basin in North America, with a drainage area of 857,300 km^2 and an average annual discharge of 6,400 m^3/s. Flows are highest in June, with greatest variability in flow occurring in May, after which discharge and the variability in discharge decline. The Upper Yukon River is turbid and silty in the summer and fall with an estimated annual suspended sediment load at Eagle of 33,000,000 tons (Brabets et al. 2000).

Hungwitchin Native Corporation owns the majority of land in the study area above the ordinary mean high water mark. Permission was granted to operate a sonar project on Hungwitchin land at

Six Mile Bend. A semi-permanent field camp consisting of 6 canvas tents on plywood platforms was constructed in 2005 on the left bank (64° 51′55.70″N, 141° 04′43.62″W), and 2 additional tents were installed in 2012. An additional tent platform with a 12 x 15 ft Weatherport portable building was constructed on the left bank 1.3 km downriver from the camp (64°52′30.84″N, 141°04′52.77″W) to house computer and sonar related equipment. A portable wooden shelter was used on the right bank to house topside sonar equipment, a wireless router, and a solar powered battery bank.

HYDROACOUSTIC EQUIPMENT

A fixed-location, split-beam sonar developed by Kongsberg Simrad was used to estimate salmon passage on the left bank. Fish passage was monitored with a model EK60 digital echosounder, which included a general-purpose transceiver and a 2.5° x 10° 120 kHz transducer. ER60 data acquisition software installed on a laptop computer connected to the echosounder collected raw data for processing. Digital files created by the ER60 software were examined with the echogram viewer program Echotastic (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication), to produce an estimate of fish passage.

The transducer was attached to 2 Hydroacoustic Technology Incorporated (HTI) model 662H single-axis rotators. Aiming was performed remotely using an HTI model 660 remote control unit that provided horizontal and vertical position readings.

A DIDSON long-range unit, manufactured by Sound Metrics Corporation, was deployed on the right bank. This sonar was operated at 1.2 MHz (high frequency option using 48 beams) for the 0–20 m range and at 0.70 MHz (low frequency option using 48 beams) for the 20–40 m range. Both the low and high frequency modes have an approximate viewing angle of 29° x 14°. A 60 m cable carried power and data between the DIDSON unit in the water and a topside breakout box. A wireless router transferred data between the breakout box and a laptop computer on the opposite bank. Sampling was controlled by DIDSON software loaded on the laptop computer. All surface electronics were housed on shore in a small, wood frame shelter.

Right bank power was supplied by a 12 V system consisting of an array of 4 solar panels (85 W), 10 batteries (6 V), a charge controller, and inverter. The solar power system was supplemented with a portable 2000 W gasoline generator and a power converter/charger. Left bank hydroacoustic equipment and computers were powered with a portable 2000 W gasoline generator running continuously.

SONAR DEPLOYMENT AND OPERATION

Each season, prior to transducer deployment, bottom profiles are checked to ensure the original sites remain acceptable for ensonification. Data were collected from transects made from bank-to-bank using a boat-mounted Lowrance LCX-15 dual frequency transducer (down-looking sonar) with a built-in Global Positioning System (GPS). A bottom profile was then generated using data files uploaded to a computer and plotted with Microsoft® Excel (Figure 3).

The split-beam sonar was deployed July 4 on the left bank. The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore. The frame was secured with sandbags and the transducer height was adjusted by sliding a mounting bar up or down along riser pipes that extended above the water. The transducer was deployed between 1.0 m and 1.5 m depth and aimed perpendicular to the current along the natural substrate. The transducer was deployed at a location with consistent flow and no eddy or slack water.

An artificial acoustic target was used at various distances from the transducer during deployment to verify that the transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beam and to test target detection at different ranges. The target, an airtight 250 ml weighted plastic bottle tied with monofilament line, was drifted downstream along the river bottom and through the acoustic beam. Several drifts were made with the target in an attempt to pass it through as much of the counting range as possible. Proper aim for the split-beam system was verified with visual interpretation of an echogram on a computer screen (i.e., with visible) but not overpowering return of bottom signal appearing over the majority of the ensonified range.

The split-beam system was aimed to ensonify a range between 2 m and 150 m when counting Chinook salmon and 2 m and 75 m when counting chum salmon. Settings for data acquisition included 256 µs transmit pulse lengths, 500 W power output, 5 pings per second at 150 m range, and 10 pings per second at 75 m range.

A portable tripod-style fish lead was constructed approximately 1.5 m downstream from the transducer to prevent fish passage inshore of the transducer and provide sufficient offshore distance for fish swimming upstream to be detected in the sonar beam. A tripod was formed from 16 freestanding lead sections constructed of 2 in diameter steel pipes connected with adjustable fittings. Aluminum stringers, approximately 2.5 m long, were then attached horizontally to the upstream side of the tripods. The sections were finished with vertical lengths of aluminum conduit 3.8 cm apart. Lead sections were placed side by side in the water at a distance between 5 m and 12 m beyond the transducer. The portability of this style of fish lead was important because of the gradual slope found on the left bank. As the water level rises and falls over the duration of the summer, the transducer and lead require frequent relocation to shallower or deeper water.

The DIDSON was deployed July 4 on the right bank. It was mounted on an aluminum frame and aimed using a manual crank-style rotator. Operators adjusted the aim by viewing the video image and relaying aiming instructions to a technician on the remote bank via handheld VHF radio. Proper aim was achieved when adequate bottom features appeared over the majority of the ensonified range (0 m to 40 m).

A fish lead was constructed with 2 m steel “T” stakes and 1.2 m high-galvanized chain link fencing. The fish lead was less than 1 m downstream from the transducer and extended 3 m offshore beyond the transducer. This distance provided sufficient offshore diversion for fish swimming upstream to be detected in the sonar beam. A short lead was appropriate for this bank because of the steep slope and short nearfield distance (0.83 m) of the DIDSON. The right bank was ensonified to a range of 40 m from the transducer, with 2 sampling zones ranged between 1–20 m and 20–40 m. Sonar control parameters included the following:

1) nearshore zone: 0.83 m window start, 20.01 m window length, high frequency mode, and 7 frames per second; and

2) offshore zone: 20.84 m window start, 20.01 m window length, low frequency mode, and 4 frames per second.

SONAR DATA PROCESSING AND PASSAGE ESTIMATION

Split-beam data were collected continuously in 60 min increments and saved to an external hard drive for tracking and counting. The operator opened each data file in an echogram viewer program (Echotastic) and marked each upstream fish track by clicking a computer mouse (Figure 4). These counts were saved as a text file and recorded on a count form.

DIDSON data was collected in 30 min samples twice each hour of the day. For the first 30 min of every hour, the DIDSON sampled the ensonified range between 1 m and 20 m (Zone 1). For the second half of each hour, the DIDSON sampled between 20 m and 40 m (Zone 2). Upstream migrating fish were counted by marking each fish track in Echotastic (Figure 4). Upstream direction of travel was verified using the Echotastic video feature. These counts were saved as a text file and recorded on a count form.

The actual count for each 30 min DIDSON sample was expanded for the full hour, and the estimated counts from Zone 1 and Zone 2 were summed for a total hourly count. The daily passage $\hat{y}$ for zone z on day d was calculated by summing the hourly passage rates for each hour as follows:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \frac{y_{dzp}}{h_{dzp}} , \quad (1)$$

where h_{dzp} is the fraction of the hour sampled on day d, zone z, period p and y_{dzp} is the count for the same sample.

Treating the systematically sampled sonar counts as a simple random sample would yield an overestimate of the variance of the total, since sonar counts are highly autocorrelated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed (Wolter 1985). The variance for the passage estimate for zone z on day d is estimated as

$$\hat{V}_{y_{dz}} = 24^2 \frac{1 - f_{dz}}{n_{dz}} \frac{\sum_{p=2}^{n_{dz}} \left(\frac{y_{dzp}}{h_{dzp}} - \frac{y_{dz,p-1}}{h_{dz,p-1}} \right)^2}{2(n_{dz} - 1)} , \quad (2)$$

where n_{dz} is the number of samples in the day (24), f_{dz} is the fraction of the day sampled (12/24 = 0.5), and y_{dzp} is the hourly count for day d in zone z for sample p. Because passage estimates are assumed independent between zones and among days, the total variance was estimated as the sum of the variances:

$$\hat{V}ar(\hat{y}) = \sum_d \sum_z \hat{V}ar(\hat{y}_{dz}) . \quad (3)$$

The counts from each split-beam and DIDSON sample were entered into a Microsoft® Excel spreadsheet where counts were adjusted for missing samples when data collection was interrupted. Brief interruptions intermittently occurred when routine maintenance (i.e., silt removal) or relocation of a transducer was required. Long-term interruptions also occurred when flooding or hazardous conditions forced removal of equipment.

Whenever a portion of a period or sample was missing on the either bank, passage was estimated by expansion based on the known portion of the sample. The number of minutes in a complete sample period m_s was divided by the number of minutes counted m_i and then multiplied by the number of fish counted x in that period i. Passage y_i was estimated as

$$\hat{y}_i = x_i\left(m_s/m_i\right). \tag{4}$$

If data from 1 or more complete sample periods were missing, the actual count was expanded for the full day, where the number of hours in a complete day h_s was divided by the number of hours counted h_i and then multiplied by the number of fish counted x in that day d. Passage $\hat{y}_d$ was estimated as

$$\hat{y}_d = x_d\left(h_s/h_d\right). \tag{5}$$

If data from 1 or more complete days x_d were missing, passage for each missing day y_d was estimated using simple linear interpolation based on the known passage y_b for the day immediately before the missing days and passage y_a for the day immediately after (x_a) the missing day(s) as

$$\hat{y}_d = y_b + x_d\left(\frac{y_a - y_b}{x_a}\right). \tag{6}$$

As an example, if data from 9 d were missing, for the estimated passage on the third missing day ($d = 3$), $x_d = 3$, and $x_a = 10$.

After editing was complete, an estimate of hourly, daily, and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone each day. The estimates produced during the field season were further reviewed postseason and adjusted as necessary.

If a large number of chum salmon were passing on the last day of sonar operation, the estimate was expanded using a second order polynomial equation. Where y_i is the i^{th} daily passage estimate, L is the count on the last day of sonar operation, d is the total number of days expanding for, and x_i is the day number being estimated (where i = 1 through total number of days expanding for):

$$y_i = \frac{L}{d^2}\left(x_i - d\right)^2. \tag{7}$$

Postseason, the Chinook and chum salmon subsistence harvest from the Eagle area upstream of the sonar site was subtracted from the adjusted sonar estimate to give a border passage estimate for each species.

SPATIAL AND TEMPORAL DISTRIBUTIONS

Fish range distributions for Chinook and chum salmon were examined postseason by importing text files containing all fish track information into *R* where the fish counts were binned by range.[2] Microsoft® Excel was used to plot the binned data and investigate the spatial distribution

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[2] R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, available for download: http://www.R-project.org

of fish passing the sonar site. Histograms of passage by hour were created in Microsoft® Excel to investigate diel patterns of migration. Run timing of Chinook and chum salmon was examined inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

SAMPLE FISHING

To monitor species composition and collect ASL and genetic samples, 2 sizes of gillnets (5.25 in and 7.5 in) were drifted through 3 zones: left bank inshore (LBI), left bank nearshore (LBN), and left bank offshore (LBF) (Figure 2). Nets were 25 fathoms long, approximately 25 ft deep, and hung "even" at a 2:1 ratio of web to corkline, with the exception that the inshore nets were approximately 8 ft deep (Table 1). Gillnet webbing consisted of Momoi MTC or MT, shade 11, double knot multifilament nylon twine

Fishing for species composition and sample collection was conducted once daily from August 1 to September 27 between approximately 0800 and 1200 on the left bank. During the sampling period, both 5.25 in and 7.5 in nets were drifted twice within each of 3 zones (inshore, nearshore and offshore), for a total of 12 drifts. Drifts were targeted to be 6 min in duration, but were shortened as necessary to avoid snags or to limit catches and thus prevent mortalities during times of high fish passage. The inshore zone drifts were referred to as "beach walks" (Fleischman et al. 1995), where 1 person held onto the shore end of the net and led it downstream along the beach while a boat drifted with the offshore end. The nearshore zone started approximately 1 net length from shore and the offshore zone started approximately 2 net lengths from shore (Figure 2). The order of drifts was 1) LBI, 2) LBN, and 3) LBF, with a minimum of 15 min between drifts in the same zone (Table 1). All drifts with 1 mesh size were completed before switching to another mesh size. Starting mesh sizes were alternated each day.

In an effort to collect more Chinook salmon ASL and genetic samples, additional fishing was conducted to target Chinook salmon. Between July 10 and July 31, fishing occurred twice per day from approximately 0800 to 1200 and again from approximately 1300 to 1700 to capture Chinook salmon. Between August 1 and August 14, Chinook salmon sample fishing was conducted once per day after species composition fishing was completed. Chinook salmon genetic and ASL samples were collected to estimate specific Canadian stock proportions and ASL composition of Chinook salmon entering Canada. On a rotating schedule, 4 different mesh sizes (5.25 in, 6.5 in, 7.5 in, and 8.5 in) were drifted over the course of the Chinook salmon run to effectively capture all size classes present (Table 1). Nets were 25 fathoms long, approximately 25 ft deep, and hung "even" at a 2:1 ratio of web to corkline. Drifts were 6 min in duration using 3 net sizes within the left bank nearshore (LBN), left bank offshore (LBF), and right bank nearshore (RBN). The right bank zone was located approximately 5 km downriver from the sonar site where river conditions were suitable for drift gillnetting on that bank (Figure 2). This resulted in a total of 9 drifts during the Chinook salmon sample-fishing period.

Each drift was recorded to the nearest second onto field data sheets: net start out SO, net full out FO, net start in SI, and net full in FI. For each drift, fishing time t, in minutes, was approximated as

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \quad (8)$$

Total effort e, in fathom-hours, of drift j with mesh size m during fishing period f in zone z on day d was calculated as

$$e_{dzfmj} = \frac{25\,t_{dzfmj}}{60}. \tag{9}$$

Captured salmon were sampled in the following ways:

For standard ASL samples, length (mideye to tail fork to nearest 1 mm) and sex (determined by external characteristics) were recorded. Samples of 3 scales from Chinook salmon and 1 scale from chum salmon were removed from the preferred area of the fish[3] (Clutter and Whitesel 1956). All scale samples were cleaned and mounted on gum cards to be aged by ADF&G ASL lab in Anchorage. These scale data were used to estimate the age composition of salmon that pass the Eagle sonar site.

For genetic stock identification (GSI), an axillary process was clipped from each salmon. Chinook salmon samples were stored individually in a vial of ethanol, while chum salmon samples were stored in bulk collections of up to 200 samples. All samples were sent to the ADF&G genetics laboratory and from there forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing. Non-salmon species were measured from nose to tail fork but were not sampled for other data. Captured fish were handled in a manner that minimized mortalities. Most captured fish were quickly sampled and returned to the river. Mortalities were distributed to local residents after sampling.

SPECIES DETERMINATION

Although the Chinook and fall chum salmon runs are considered discrete in time, some temporal overlap does occur. Inseason, tentative dates are chosen based on sonar counts, gillnet catches, and local harvest to represent the last day of the Chinook salmon run and the first day of the chum salmon run. After thorough postseason examination of the sample fishery data, these tentative dates are updated to more accurately represent the runs. Sample fishery information was used to determine the specific date after which sonar counts were classified as chum salmon. This was ascertained using reverse-cumulative Chinook salmon catches and cumulative chum salmon catches. Estimates are reported as Chinook salmon for days d, such that

$$\sum_{d=n,i=Chinook}^{d} C_{id} > \sum_{d=1,i=chum}^{d} C_{id}, \tag{10}$$

where n is most current day of fishing and C is the catch of species i on day d. The species crossover date is defined as the day where the inequality is no longer met.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Climatic and hydrologic observations were collected at approximately 1800 each day. Reported stream levels are taken from the U.S. Geological Survey's gaging station at Eagle, although water levels were carefully monitored at the sonar site as well. Surface water temperature was measured approximately 30 cm below the surface with a HOBO U22™ water temperature data

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[3] On the left side approximately 2 rows above the lateral line, in an area transected by a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956).

logger. The data logger was suspended from a float tied to the transducer stand and set to record 6 times per day. Air temperature, wind velocity, and wind direction were measured daily with a Kestrel 2000 handheld weather meter. Other daily observations included occurrence of precipitation and percent cloud cover.

RESULTS

SONAR DEPLOYMENT

In 2012, both the right and left bank transducers were deployed in approximately the same locations that have been used in recent years. On July 4, the left bank sonar was deployed approximately 800 m downriver from the camp and the right bank sonar was deployed across the river approximately 700 m downriver from the camp (Figures 2 and 3). The left bank profile was approximately linear, extending approximately 265 m to the thalweg at a 2.8° slope. The right bank profile was less linear, shorter and steeper, extending approximately 120 m to the thalweg at a 6.1° slope. The substrate at Six Mile Bend was large cobble to small boulder on the right bank and small to medium sized cobble and silt on the left bank.

CHINOOK AND CHUM SALMON PASSAGE ESTIMATION

Inseason, August 22 was tentatively determined to be the last day of the Chinook salmon run based on relatively low sonar counts, project gillnet catches, and harvest information gathered from local subsistence fishermen. Fish range distribution from the sonar also was a primary indicator that the salmon run was changing from Chinook to chum salmon. The inseason species changeover date was adjusted postseason after thorough examination of sample fishery information. Analysis of reverse-cumulative Chinook catches and cumulative chum salmon catches showed that August 19 was the last date when the overall Chinook catch was more than the overall chum salmon catch. Reverse-cumulative Chinook catch and cumulative chum salmon catch were plotted by day from just prior to the date of the first chum salmon capture (Figure 5). The 2 lines cross at the point when the number of chum caught equals the number of Chinook salmon caught subsequent to that point.

The total passage estimate at the Eagle sonar site was 34,747 Chinook salmon from July 4 to August 19, 2012 (Table 2). The first quarter point (July 24), midpoint (July 29), and third quarter point (August 4) indicated the 2012 Chinook salmon run was 4 to 5 d late compared to 2006–2011 mean quartile passage dates. Peak daily passage estimate of 2,019 Chinook salmon occurred on July 27, and 143 fish passed on August 19, the last day of estimating Chinook salmon passage (Table 2 and Figure 6). Sampling time missed during this period because of routine maintenance, system diagnostic tests, system malfunction, moving and aiming the transducer, or flooding included 74.0 h on the left bank, 27.8 h on the right bank Zone 1, and 31.6 h on the right bank Zone 2 (Table 3). Sometimes the collection software from the split beam sonar overran the sample time, resulting in a sample that was more than an hour long (Table 3). If at the end of a day the sample time was more than 24 h (1,440 min), then the time in the table would show as negative. In this case, fish may have been subtracted from the estimate, resulting in a negative number of fish. Postseason, the subsistence harvest from the Eagle area upstream of the sonar site was subtracted from the sonar estimate to produce a border passage estimate of 34,656 Chinook salmon (Table 4). The preliminary subsistence harvest from the Eagle area upstream of the sonar was 91 Chinook salmon (Deena Jallen, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

The total fall chum salmon passage estimate was 147,710 fish from August 20 to October 6 (Table 5). The first quarter point (September 11), midpoint (September 22), and third quarter point (September 26), indicated that the 2012 chum salmon run was 1 to 5 d early compared to 2006–2011 mean quartile passage dates that include end of season expansions. Fall chum salmon passage peaked on September 23 with a daily estimate of 9,121 fish (Table 5 and Figure 6). Sampling time missed during this period because of routine maintenance, system diagnostic tests, system malfunction, moving and aiming the transducer, or flooding included 19.3 h on the left bank, 0.005 h on the right bank Zone 1, and 3.5 h on the right bank Zone 2 (Table 6). Although chum salmon passage was decreasing on the last day of operation, 1,576 fish (approximately 1.1% of total) passed on October 6. Continuing chum salmon passage when the project was terminated prompted expansion of the sonar estimate, which was adjusted to 153,248 chum salmon (Table 4 and Figure 6). The expansion was calculated using a second order polynomial equation extended to October 18. October 18 was chosen based on what was considered to be the most likely run timing scenario, derived from 1982 to 2008 historical data collected at the DFO mark–recapture fish wheel project near the U.S./Canada border. After the end of season expansion was included in the chum salmon estimate, the first quarter point was September 11, the midpoint was September 22, and third quarter point was September 27. Postseason, the subsistence harvest from the Eagle area upstream of the sonar was subtracted from the sonar estimate to produce a border passage estimate of 141,648 fish (Table 4). The preliminary subsistence harvest from the Eagle area was 11,600 fish (Deena Jallen, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore-oriented on both banks (Figures 7 and 8). On the left bank during the Chinook salmon run, 94% of the fish were detected within 75 m of the transducer and 99% within 105 m. On the right bank, 95% of the fish were detected within 26 m of the transducer and 99% within 34 m. During the fall chum salmon run on the left bank, 93% of the fish were detected within 20 m of the transducer and 99% within 35 m. On the right bank, 95% of the fish were detected within 8 m of the transducer and 99% within 14 m. The percentage of fish passage estimated by bank for the Chinook salmon season was approximately 82% on the left bank and 18% on the right bank. During the fall chum salmon run, approximately 79% migrated on the left bank and 21% on the right bank.

On average, Chinook salmon passage along the left and right bank did not fluctuate much between daylight hours and periods of darkness (Figure 9). On average more chum salmon passed along the right bank during daylight hours compared to periods of darkness while fewer chum salmon passed along the left bank during daylight hours compared to periods of darkness (Figure 10). Overall, when both banks are combined, there was very little diel fluctuation at the project site for both species.

SAMPLE FISHING

A total of 344 Chinook and 647 chum salmon were captured in drift gillnets between July 10 and September 27 (Table 7). Fishing for species composition and sample collection occurred from August 1 to September 27, and additional Chinook salmon sample fishing occurred from July 10 to August 14. Drifts during species composition fishing caught 84 Chinook and 647 chum salmon. Drifts during Chinook salmon sample fishing caught 260 Chinook and 0 chum salmon (Tables 8 and 9). Additionally, 1 sheefish *Stenodus leucichthys* was captured during species composition fishing. There were 0 Chinook and 2 chum salmon capture mortalities. An additional 3 Chinook salmon were observed to have clipped adipose fins indicating they held coded wire tags from the hatchery in Whitehorse, Yukon. These fish were retained and the heads sent to the ADF&G Mark, Tag and Age Lab in Juneau, Alaska. The fish were then distributed to local area residents and added to the total subsistence harvest.

Chinook salmon samples collected from driftnets included 181 (52.6%) males and 163 (47.4%) females. Chum salmon samples from driftnets included 375 (58.0%) males and 271 (42.0%) females. ASL samples from 344 Chinook and 642 chum salmon were collected and sent to the ADF&G age determination laboratory in Anchorage, Alaska for processing. Genetic samples from 344 Chinook and 645 chum salmon were collected and sent to the ADF&G genetics laboratory in Anchorage, Alaska and from there forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Water temperature decreased over the course of the season with a maximum daily recording of 18°C and a minimum of 3°C (Appendix A1). The water level was high upon arrival at the project site on July 1 and remained higher than the 1993 through 2011 historic mean the entire season, with 2 brief exceptions: August 25–29 and September 10–13 (Figure 11). Water level decreased over the duration of the season, with several temporary and dramatic increases following substantial rain events. Overall, between July 1 and October 6 the water level decreased 9.7 ft from 21.1 ft to 11.9 ft. The lowest water level recorded during the season was 11.9 ft on October 6, while the highest was 21.58 ft on July 2.

DISCUSSION

The split-beam and DIDSON systems performed well over the entire season with no major technical difficulties or failures. Only when water levels were extremely high and the Yukon River demonstrated an abnormally heavy silt load were sonar operations interrupted. Heavy rains and flood events characterized July and August. Rapid water level fluctuations coupled with substantial debris necessitated moving the transducers and fish leads to deeper or shallower water. The left bank fish lead collapsed during high water events, and multiple panels had to be recovered and removed from the water on occasions when the high water flow and debris load compromised their stability. When the silt load was exceptionally high, sonar detection ranges were diminished. Detection range for the left bank sonar was reduced to approximately half of the normal counting range for a total of 46 h August 12, August 13, and August 14, during the Chinook salmon run. Left bank sonar signal strength decreased markedly at close range on August 12, and abnormally low counts compared to previous hours indicated that fish were being missed by the sonar. Signal strength was not considered dependable for fish counts again until August 13. Detection range for the right bank sonar also declined for 20 h on August 13; however, the decrease in hourly counts was not as pronounced as on left bank. Fish passage estimates between 1600 on August 12 and 1300 on August 14 on the left bank, and from 0400 to 2300 on the right bank, were interpolated.

In contrast, weather and river conditions during the chum salmon run in late August and September were very favorable for sonar operation. The DIDSON's wide vertical beam angle (14°) is well suited for the right bank, where the profile is steep and less linear than the left bank.

The split-beam system worked without malfunction and appeared to have satisfactory detection nearshore while still detecting targets adequately at either 150 m or 75 m.

The Chinook salmon border passage estimate of 34,656 was 36.5% below the 2005 to 2011 average border passage estimate of 54,611 and was not enough to meet the interim management escapement goal (IMEG) of 42,500 to 55,000. The fall chum salmon border passage estimate of 141,648 was 22.2% below the 2006 to 2011 average border passage estimate of 182,120. This was more than enough to meet the IMEG of 70,000 to 104,000.

Based on sample fishing results and range distributions observed with the sonar, very few fish migrate upstream in the unensonified portion of the river. The majority of fish migrate within 40 m of shore on both banks. The right bank DIDSON was aimed to ensonify to a range of 40 m, and the left bank split-beam system was aimed to ensonify to a range of 150 m. Because chum salmon tend to swim closer to shore, the range for the left bank split-beam system was reduced to 75 m on August 29 to allow faster ping rates and improved detection near shore. The diel migration pattern of chum salmon observed was similar to past years. Average upstream migration was greatest in periods of darkness or suppressed light on the left bank and greatest during daylight hours on the right bank. The average diel migration pattern of Chinook salmon was similar to past years in that there was not much, if any, difference in passage between day and night.

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TABLES AND FIGURES

Table 1.–Net schedules for species composition and additional Chinook salmon samples, all zones, 2012.

		Mesh size (inches)		
Sampling purpose	Day	Drift 1	Drift 2	Drift 3
Species composition	1	5.25	7.50	
	2	7.50	5.25	
Additional Chinook salmon samples	1	5.25	6.50	7.50
	2	7.50	8.50	6.50
	3	6.50	5.25	8.50
	4	8.50	7.50	5.25

Table 2.–Estimated daily and cumulative Chinook salmon passage by bank, Eagle sonar, 2012.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
7/04 [a]	2	0	2	2	0	2	0.00
7/05	0	0	0	2	0	2	0.00
7/06	0	0	0	2	0	2	0.00
7/07	0	2	2	2	2	4	0.00
7/08	0	0	0	2	2	4	0.00
7/09	5	4	9	7	6	13	0.00
7/10	3	27	30	10	33	43	0.00
7/11	4	28	32	14	61	75	0.00
7/12	5	23	28	19	84	103	0.00
7/13	15	39	54	34	123	157	0.00
7/14	40	56	96	74	179	253	0.01
7/15	85	90	175	159	269	428	0.01
7/16	114	88	202	273	357	630	0.02
7/17	183	144	327	456	501	957	0.03
7/18	268	154	422	724	655	1,379	0.04
7/19	503	204	707	1,227	859	2,086	0.06
7/20	737	180	917	1,964	1,039	3,003	0.09
7/21	836	144	980	2,800	1,183	3,983	0.11
7/22	1,040	298	1,338	3,840	1,481	5,321	0.15
7/23	1,223	358	1,581	5,063	1,839	6,902	0.20
7/24	1,334	376	1,710	6,397	2,215	8,612	0.25
7/25	1,514	293	1,807	7,911	2,508	10,419	0.30
7/26	1,491	312	1,803	9,402	2,820	12,222	0.35
7/27	1,729	290	2,019	11,131	3,110	14,241	0.41
7/28	1,672	310	1,982	12,803	3,420	16,223	0.47
7/29	1,626	266	1,892	14,429	3,686	18,115	0.52
7/30	1,597	285	1,882	16,026	3,971	19,997	0.58
7/31	1,263	282	1,545	17,289	4,253	21,542	0.62
8/01	1,281	195	1,476	18,570	4,448	23,018	0.66
8/02	1,233	158	1,391	19,803	4,606	24,409	0.70
8/03	1,038	196	1,234	20,841	4,802	25,643	0.74
8/04	1,110	140	1,250	21,951	4,942	26,893	0.77
8/05	1,059	152	1,211	23,010	5,094	28,104	0.81
8/06	1,006	151	1,157	24,016	5,245	29,261	0.84
8/07	893	100	993	24,909	5,345	30,254	0.87
8/08	711	112	823	25,620	5,457	31,077	0.89
8/09	634	150	784	26,254	5,607	31,861	0.92
8/10	531	92	623	26,785	5,699	32,484	0.93
8/11	468	80	548	27,253	5,779	33,032	0.95
8/12 [b]	339	50	389	27,592	5,829	33,421	0.96
8/13 [b]	259	72	331	27,851	5,901	33,752	0.97
8/14 [b]	178	54	232	28,029	5,955	33,984	0.98
8/15	170	40	210	28,199	5,995	34,194	0.98
8/16	120	18	138	28,319	6,013	34,332	0.99
8/17	67	76	143	28,386	6,089	34,475	0.99
8/18	81	48	129	28,467	6,137	34,604	1.00
8/19 [c]	101	42	143	28,568	6,179	34,747	1.00
SE						199	

-continued-

Table 2.–Page 2 of 2.

Note: The large boxed area identifies second and third quartile of run and inside bold box identifies median day of passage.

[a] Right and left bank sonar operational.

[b] High silt load and debris affected counts, counts interpolated.

[c] Last day of Chinook salmon estimation.

Table 3.–Number of minutes by bank and day that were adjusted to calculate the hourly or daily Chinook salmon passage, and the resulting number of fish either added or subtracted from estimate.

	Left bank (0–150 m)		Right bank (0–20 m)		Right bank (20–40 m)	
Date	Minutes	Fish	Minutes	Fish	Minutes	Fish
7/4	781.6	1	390	0	390	0
7/5	372.6	0	210.0	0	180.0	0
7/6	7.6	0	90.0	0	60.0	0
7/7	94.7	0	5.0	0	30.0	0
7/8	129.9	0	0.0	0	0.0	0
7/9	4.8	0	0.0	0	30.0	0
7/10	5.2	0	56.5	3	120.0	0
7/11	5.3	0	150.0	6	97.0	0
7/12	0.6	0	30.6	1	48.1	0
7/13	5.6	0	60.0	3	39.9	0
7/14	4.9	0	0.0	0	0.0	0
7/15	6.3	0	0.0	0	0.0	0
7/16	5.0	0	0.0	0	0.0	0
7/17	5.6	0	0.0	0	0.0	0
7/18	4.2	0	0.0	0	0.0	0
7/19	5.4	0	39.0	10	30.0	0
7/20	5.1	0	0.0	0	30.0	0
7/21	4.8	0	0.0	0	0.0	0
7/22	5.1	0	0.0	0	0.0	0
7/23	5.6	0	0.0	0	0.0	0
7/24	5.7	0	0.0	0	0.0	0
7/25	4.3	0	4.0	0	30.0	1
7/26	6.2	2	0.0	0	0.0	0
7/27	5.8	0	0.0	0	0.0	0
7/28	6.9	2	0.0	0	0.0	0
7/29	8.2	4	0.0	0	0.0	0
7/30	9.1	3	30.0	11	30.0	0
7/31	3.8	-3	0.0	0	0.0	0
8/1	9.3	2	-28.8	-10	30.0	1
8/2	9.1	1	0.0	0	60.0	2
8/3	9.2	0	0.0	0	0.0	0
8/4	9.0	0	0.0	0	0.0	0
8/5	9.0	0	0.0	0	0.0	0
8/6	10.1	1	0.0	0	30.0	7
8/7	9.2	0	0.0	0	0.0	0
8/8	9.4	0	0.0	0	0.0	0
8/9	9.1	0	30.0	6	30.0	0
8/10	8.9	0	0.0	0	0.0	0
8/11	8.7	0	0.0	0	0.0	0
8/12	485.9	113	0.0	0	0.0	0
8/13	1440.0	259	600.0	60	600.0	0
8/14	843.8	104	0.0	0	0.0	0
8/15	9.3	0	0.0	0	0.0	0
8/16	9.3	0	0.0	0	30.0	0
8/17	10.4	0	0.0	0	0.0	0
8/18	18.5	1	0.0	0	0.0	0
8/19	9.1	0	0.0	0	0.0	0
Total	4,437.2 (74.0 h)	490	1,666.3 (27.8 h)	90	1,895.0 (31.6 h)	11

Note: Negative numbers are result of collection software over running the sample period.

Table 4.–Eagle sonar estimate, Eagle area subsistence harvest, and border passage estimates, 2005–2012.

	Sonar estimate		Eagle area subsistence harvest		U.S. sonar mainstem border passage estimate	
Date	Chinook	chum	Chinook	chum	Chinook	chum
2005	81,528	ND	2,566	ND	78,962	ND
2006	73,691	236,386	2,303	17,775	71,388	218,611
2007	41,697	282,670 [a]	1,999	18,691	39,698	263,979
2008	38,097	193,397 [a]	815	11,381	37,282	182,016
2009	69,957	101,734 [a]	382	6,995	69,575	94,739
2010	35,074	132,930 [a]	604	11,432	34,470	121,498
2011	51,271	224,355 [a]	370	12,477	50,901	211,878
2012	34,747	153,248 [a]	91 [b]	11,600 [b]	34,656	141,648

Note: Estimates for subsistence caught salmon between the sonar site and border (Eagle area) prior to 2008 include an unknown portion caught below the sonar site. This number is most likely in the hundreds for Chinook salmon, and a few thousand for chum salmon. Starting in 2008, the estimates for subsistence caught salmon only include salmon harvested between the sonar site and the U.S./Canada border.

[a] Expanded sonar estimate, includes expansion for fish that may have passed after sonar operations ceased.

[b] Subsistence estimates for 2012 are preliminary.

Table 5.–Estimated daily and cumulative chum salmon passage by bank, Eagle sonar, 2012.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
8/20 [a]	106	34	140	106	34	140	0.00
8/21	93	28	121	199	62	261	0.00
8/22	82	36	118	281	98	379	0.00
8/23	145	42	187	426	140	566	0.00
8/24	89	44	133	515	184	699	0.00
8/25	64	36	100	579	220	799	0.01
8/26	64	62	126	643	282	925	0.01
8/27	166	46	212	809	328	1,137	0.01
8/28	446	54	500	1,255	382	1,637	0.01
8/29	496	68	564	1,751	450	2,201	0.01
8/30	465	118	583	2,216	568	2,784	0.02
8/31	988	152	1,140	3,204	720	3,924	0.03
9/01	1,516	262	1,778	4,720	982	5,702	0.04
9/02	1,526	352	1,878	6,246	1,334	7,580	0.05
9/03	1,969	582	2,551	8,215	1,916	10,131	0.07
9/04	1,951	472	2,423	10,166	2,388	12,554	0.08
9/05	2,419	534	2,953	12,585	2,922	15,507	0.10
9/06	2,745	612	3,357	15,330	3,534	18,864	0.13
9/07	3,003	890	3,893	18,333	4,424	22,757	0.15
9/08	3,107	880	3,987	21,440	5,304	26,744	0.18
9/09	3,139	704	3,843	24,579	6,008	30,587	0.21
9/10	3,122	586	3,708	27,701	6,594	34,295	0.23
9/11	2,609	684	3,293	30,310	7,278	37,588	0.25
9/12	2,444	758	3,202	32,754	8,036	40,790	0.28
9/13	2,323	648	2,971	35,077	8,684	43,761	0.30
9/14	2,141	557	2,698	37,218	9,241	46,459	0.31
9/15	1,767	438	2,205	38,985	9,679	48,664	0.33
9/16	1,505	396	1,901	40,490	10,075	50,565	0.34
9/17	1,748	454	2,202	42,238	10,529	52,767	0.36
9/18	1,991	594	2,585	44,229	11,123	55,352	0.37
9/19	2,965	1,108	4,073	47,194	12,231	59,425	0.40
9/20	4,365	1,706	6,071	51,559	13,937	65,496	0.44
9/21	5,697	1,834	7,531	57,256	15,771	73,027	0.49
9/22	6,692	1,650	8,342	63,948	17,421	81,369	0.55
9/23	7,057	2,064	9,121	71,005	19,485	90,490	0.61
9/24	6,220	1,704	7,924	77,225	21,189	98,414	0.67
9/25	6,753	458	7,211	83,978	21,647	105,625	0.72
9/26	6,336	340	6,676	90,314	21,987	112,301	0.76
9/27	5,454	292	5,746	95,768	22,279	118,047	0.80
9/28	5,162	480	5,642	100,930	22,759	123,689	0.84
9/29	3,977	938	4,915	104,907	23,697	128,604	0.87
9/30	3,541	718	4,259	108,448	24,415	132,863	0.90
10/01	2,550	882	3,432	110,998	25,297	136,295	0.92
10/02	2,440	742	3,182	113,438	26,039	139,477	0.94
10/03	1,968	592	2,560	115,406	26,631	142,037	0.96
10/04	1,510	594	2,104	116,916	27,225	144,141	0.98
10/05	1,235	758	1,993	118,151	27,983	146,134	0.99
10/06 [b]	971	605	1,576	119,122	28,588	147,710	1.00
SE						603	

-continued-

Table 5.–Page 2 of 2.

Note: The large boxed area identifies second and third quartile of run and inside bold box identifies median day of passage.
[a] First day of chum salmon counts..
[b] Last day of sonar operation.

Table 6.–Number of minutes by bank and day that were adjusted, to calculate the hourly or daily chum salmon passage, and the resulting number of fish either added or subtracted from estimate.

	Left bank (0–75 m)		Right bank (0–20 m)		Right bank (20–40 m)	
Date	Minutes	Fish	Minutes	Fish	Minutes	Fish
8/20	9.2	0	0.0	0	30.0	0
8/21	12.3	0	0.0	0	0.0	0
8/22	546	31	0.0	0	0.0	0
8/23	374.3	40	0.0	0	0.0	0
8/24	5.9	0	0.0	0	0.0	0
8/25	5.9	0	0.0	0	0.0	0
8/26	6.6	0	0.0	0	0.0	0
8/27	6	0	0.0	0	0.0	0
8/28	7	0	0.0	0	0.0	0
8/29	6.6	1	1.0	0	0.0	0
8/30	1	-1	0.0	0	0.0	0
8/31	6	3	0.0	0	30.0	0
9/1	7	6	0.0	0	0.0	0
9/2	7.9	4	0.0	0	0.0	0
9/3	8.1	9	0.0	0	0.0	0
9/4	-0.5	-1	0.0	0	0.0	0
9/5	4.8	3	0.0	0	0.0	0
9/6	-0.8	-5	0.0	0	30.0	0
9/7	1.7	5	0.0	0	0.0	0
9/8	-1.8	0	0.0	0	0.0	0
9/9	3.3	13	0.0	0	0.0	0
9/10	-1	1	0.0	0	0.0	0
9/11	5.3	12	0.0	0	0.0	0
9/12	7.1	14	0.0	0	0.0	0
9/13	-0.1	2	0.0	0	0.0	0
9/14	16.4	15	1.5	1	60.0	0
9/15	14.7	16	0.0	0	0.0	0
9/16	14.2	14	0.0	0	0.0	0
9/17	29.7	37	0.0	0	0.0	0
9/18	2.3	1	0.0	0	0.0	0
9/19	3.8	7	0.0	0	0.0	0
9/20	3	6	0.0	0	0.0	0
9/21	2.1	4	0.0	0	0.0	0
9/22	2.1	4	0.0	0	0.0	0
9/23	2.2	7	0.0	0	0.0	0
9/24	1.9	6	0.0	0	0.0	0
9/25	2.7	11	0.0	0	0.0	0
9/26	3.9	15	0.0	0	30.0	0
9/27	4.5	13	0.0	0	0.0	0
9/28	6.6	25	0.0	0	0.0	0
9/29	7	22	0.0	0	0.0	0
9/30	6.6	22	0.0	0	0.0	0
10/1	7	12	0.0	0	0.0	0
10/2	-0.7	1	0.0	0	0.0	0
10/3	1.5	5	0.0	0	0.0	0
10/4	-0.9	0	0.0	0	0.0	0
10/5	-1.1	0	0.0	0	0.0	0
10/6	2.5	0	-2.7	-5	30.0	0
Total	1,159.8 (19.3 h)	380	-0.3 (.005 h)	-4	210.0 (3.5 h)	0

Note: Negative numbers are result of collection software over running sample period.

Table 7.–Fish caught with gillnets at the Eagle sonar project site, 2012.

Species	Species composition fishing	Chinook salmon sample fishing	Total
Chinook	84	260	344
chum	647	0	647
sheefish	1	0	1
Total	732	260	992

Table 8.–Species composition fishing effort, catch, and percentage for Chinook and chum salmon, by zone and mesh size, Eagle sonar project site, 2012.

Zone	Mesh size (inches)	Effort (fathom hours)	Chinook Catch	Chinook Percent	Chum Catch	Chum Percent
LBI	5.25	331.48	6	7.1	416	64.3
	7.50	312.06	3	3.6	106	16.4
Total		643.54	9	10.7	522	80.7
LBN	5.25	326.76	28	33.3	90	13.9
	7.50	317.10	42	50.0	32	4.9
Total		643.86	70	83.3	122	18.8
LBF	5.25	308.85	0	0.0	0	0.0
	7.50	310.48	5	6.0	3	0.5
Total		619.33	5	6.0	3	0.5
Grand total		1906.73	84	100.0	647	100.0

Note: LBI = left bank inshore, LBN = left bank nearshore, LBF = left bank offshore.

Table 9.–Chinook salmon sample fishing effort, catch, and percentage for Chinook and chum salmon, by zone and mesh size, Eagle sonar project site, 2012.

Zone	Mesh size (inches)	Effort (fathom hours)	Chinook Catch	Chinook Percent	Chum Catch	Chum Percent
LBN	5.25	117.14	37	14.2	0	0.0
	6.50	119.03	30	11.5	0	0.0
	7.50	132.91	47	18.1	0	0.0
	8.50	117.77	34	13.1	0	0.0
Total		486.85	148	56.9	0	0.0
RBN	5.25	115.59	31	11.9	0	0.0
	6.50	118.36	24	9.2	0	0.0
	7.50	134.64	38	14.6	0	0.0
	8.50	117.49	16	6.2	0	0.0
Total		486.08	109	41.9	0	0.0
LBF	5.25	111.64	1	0.4	0	0.0
	6.50	117.06	1	0.4	0	0.0
	7.50	129.70	1	0.4	0	0.0
	8.50	112.00	0	0.0	0	0.0
Total		470.40	3	1.2	0	0.0
Grand total		1,443.33	260	100.0	0	0.0

Note: LBI = left bank inshore, RBN = right bank nearshore, LBF = left bank offshore.

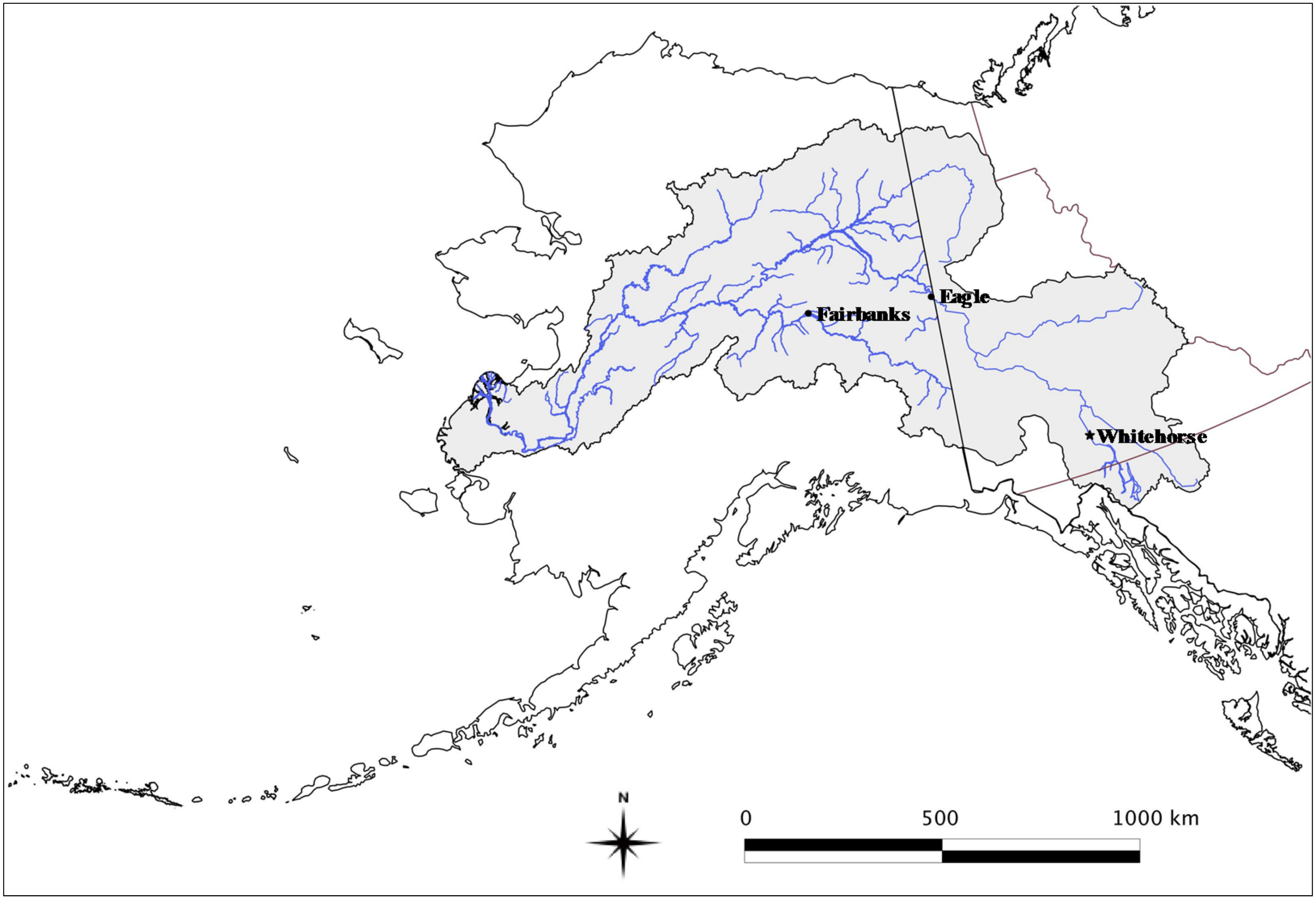

Figure 1.–Yukon River drainage.

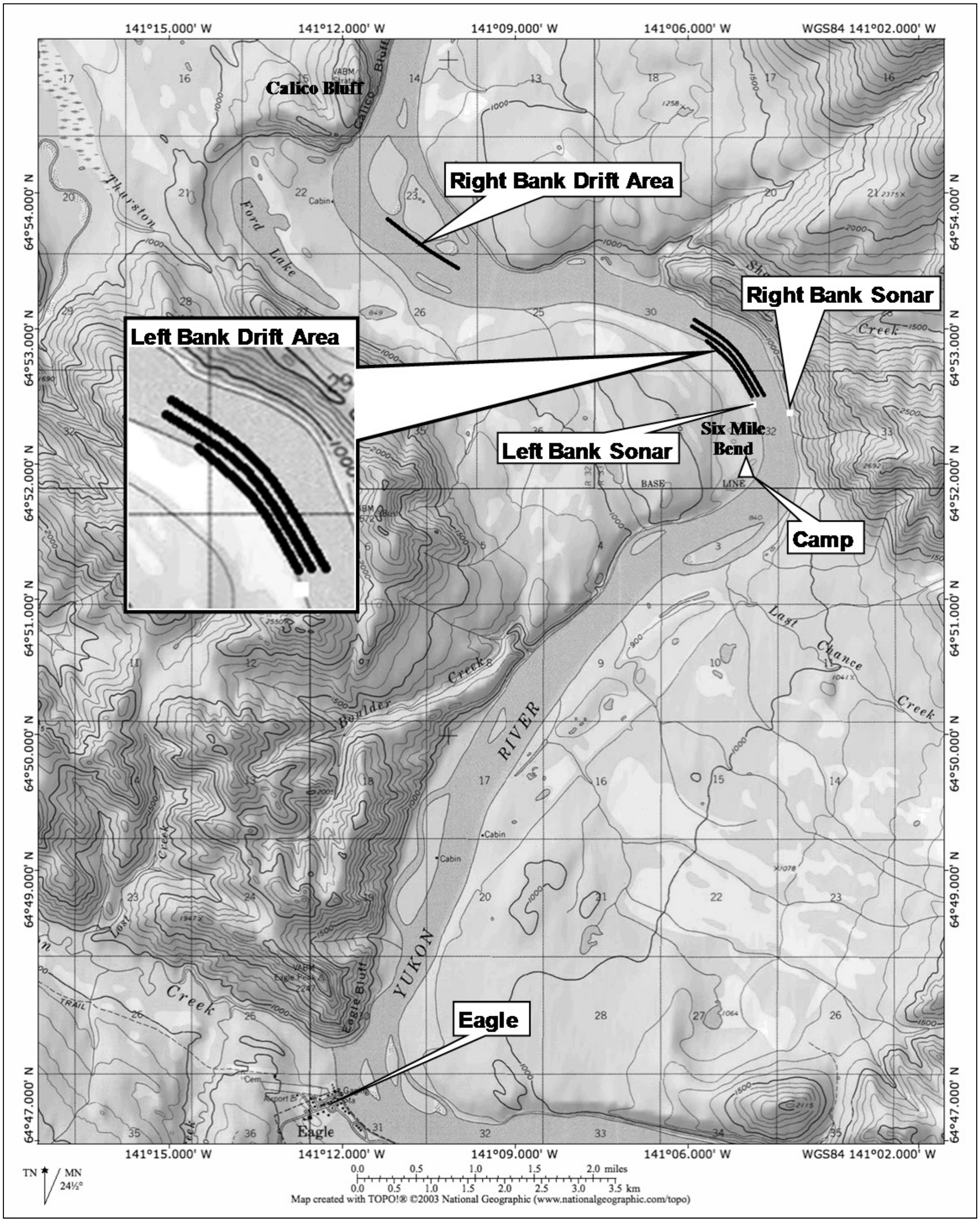

Figure 2.–Eagle sonar project site at Six Mile Bend, showing sonar and drift gillnet fishing locations.

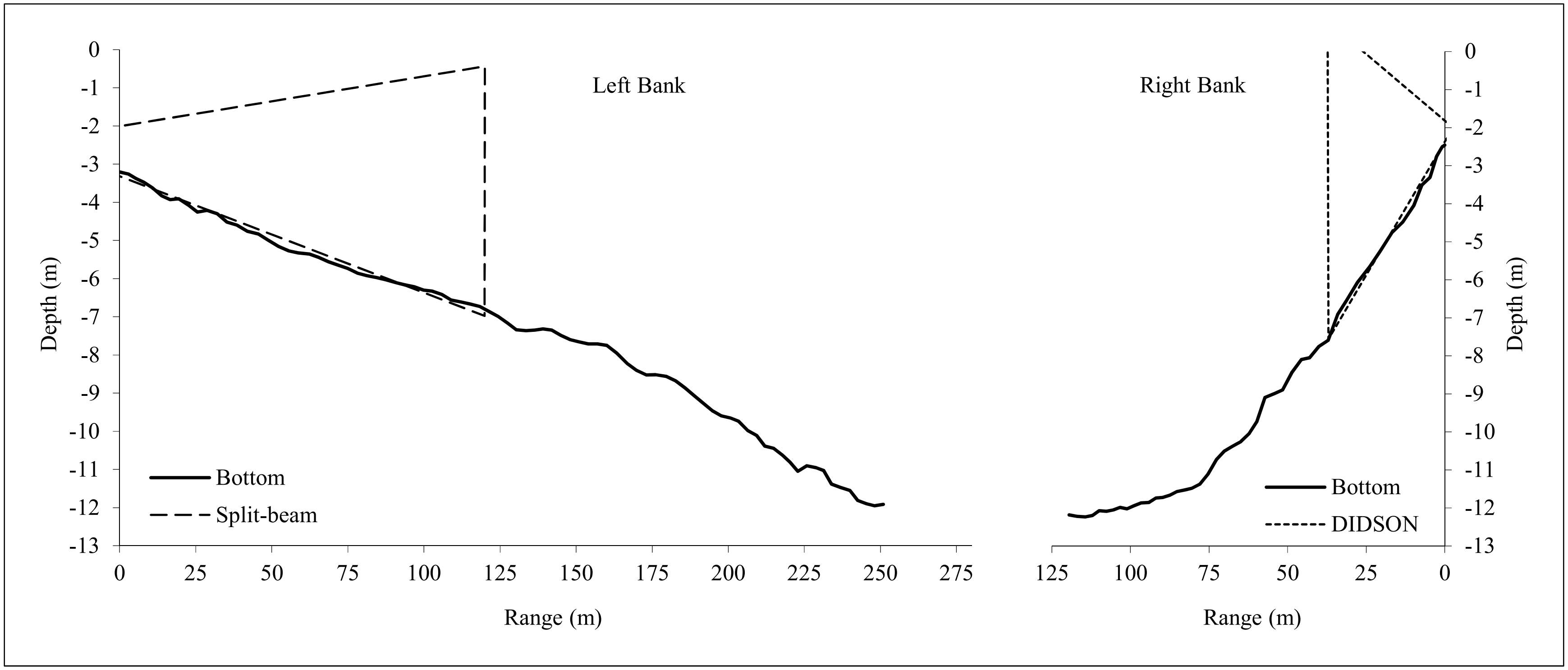

Figure 3.–Depth profile (downstream view), and ensonified zones of Yukon River at Eagle sonar project site, 2012.

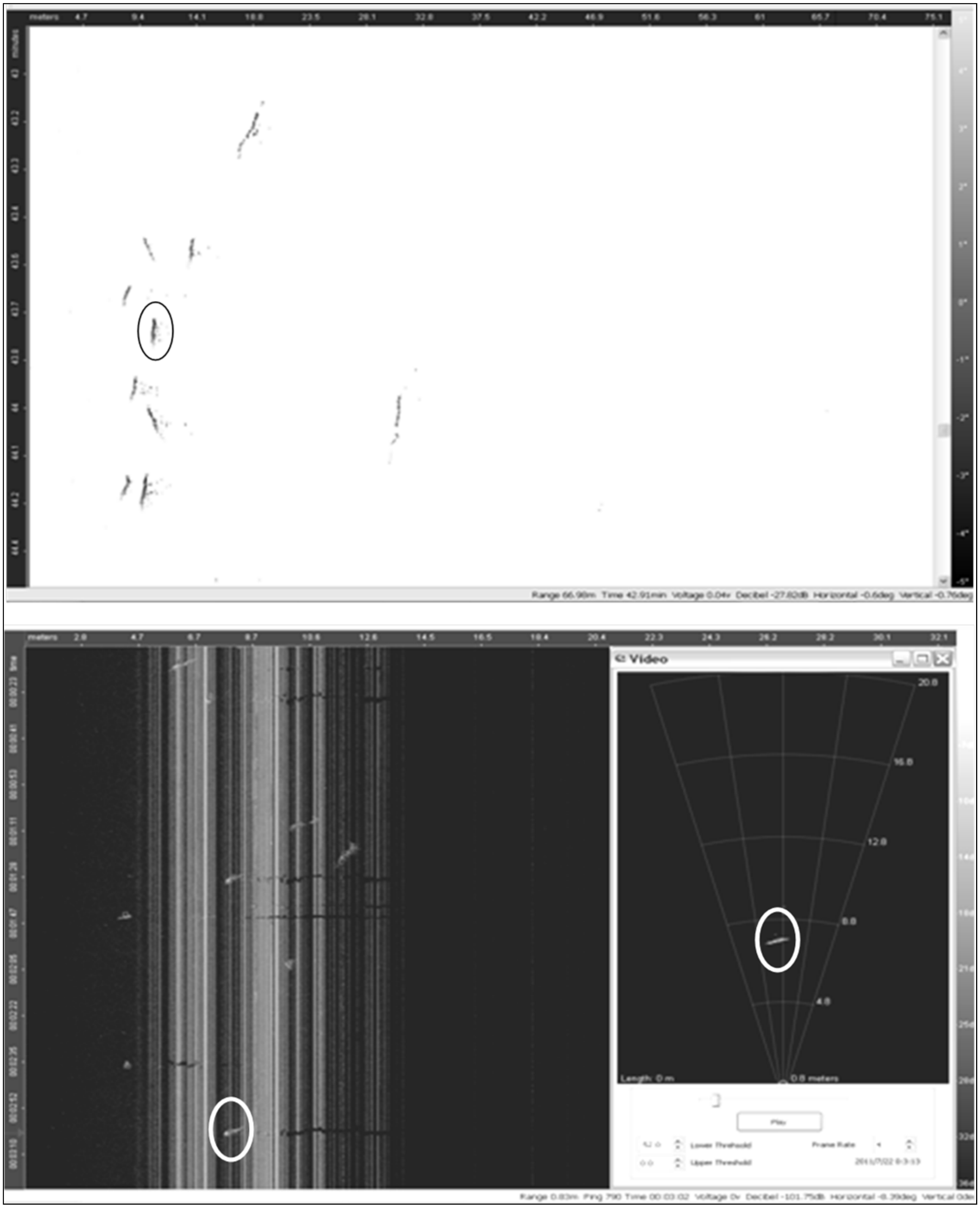

Figure 4.–Screenshots of echograms used to count fish from split-beam sonar data files (top), and DIDSON data files (bottom).

Note: Ellipse encompasses typical upstream migrating salmon.

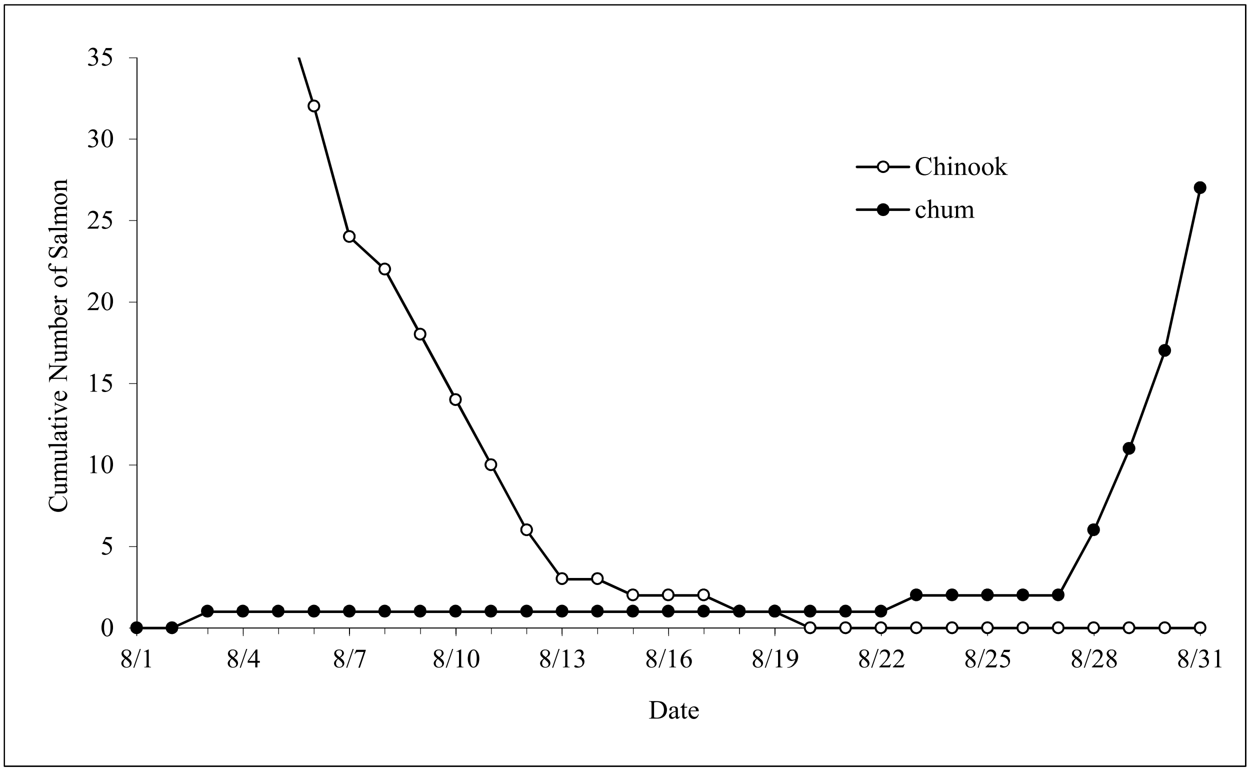

Figure 5.–Species changeover dates (August 19–20) determined from reverse cumulative Chinook and cumulative chum salmon catches at the Eagle sonar project site, 2012.

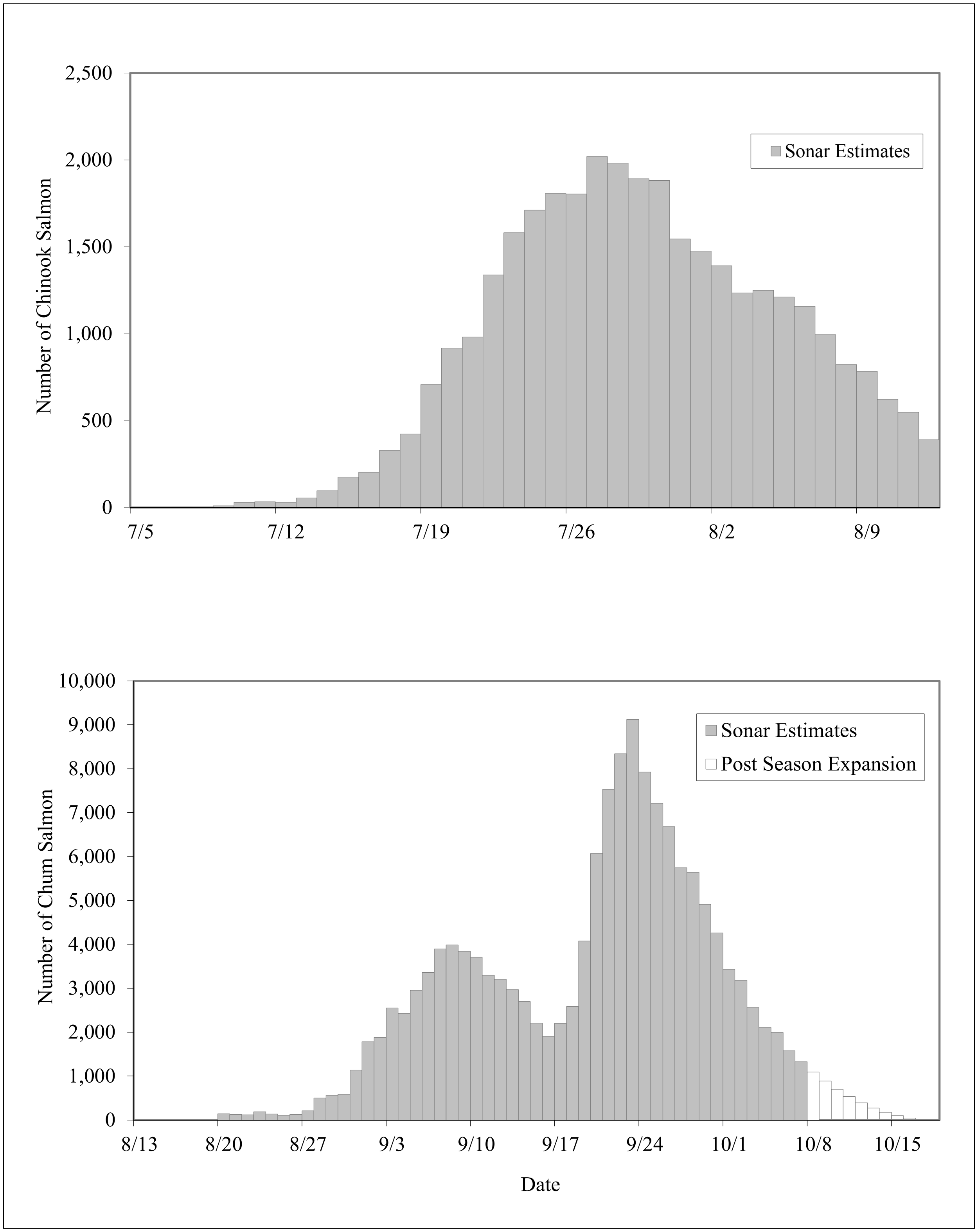

Figure 6.–Daily sonar estimates for Chinook salmon, July 4 through August 19, 2012 (top), and daily sonar estimates with postseason chum salmon expansion estimates for chum salmon, August 20 through October 18 (bottom).

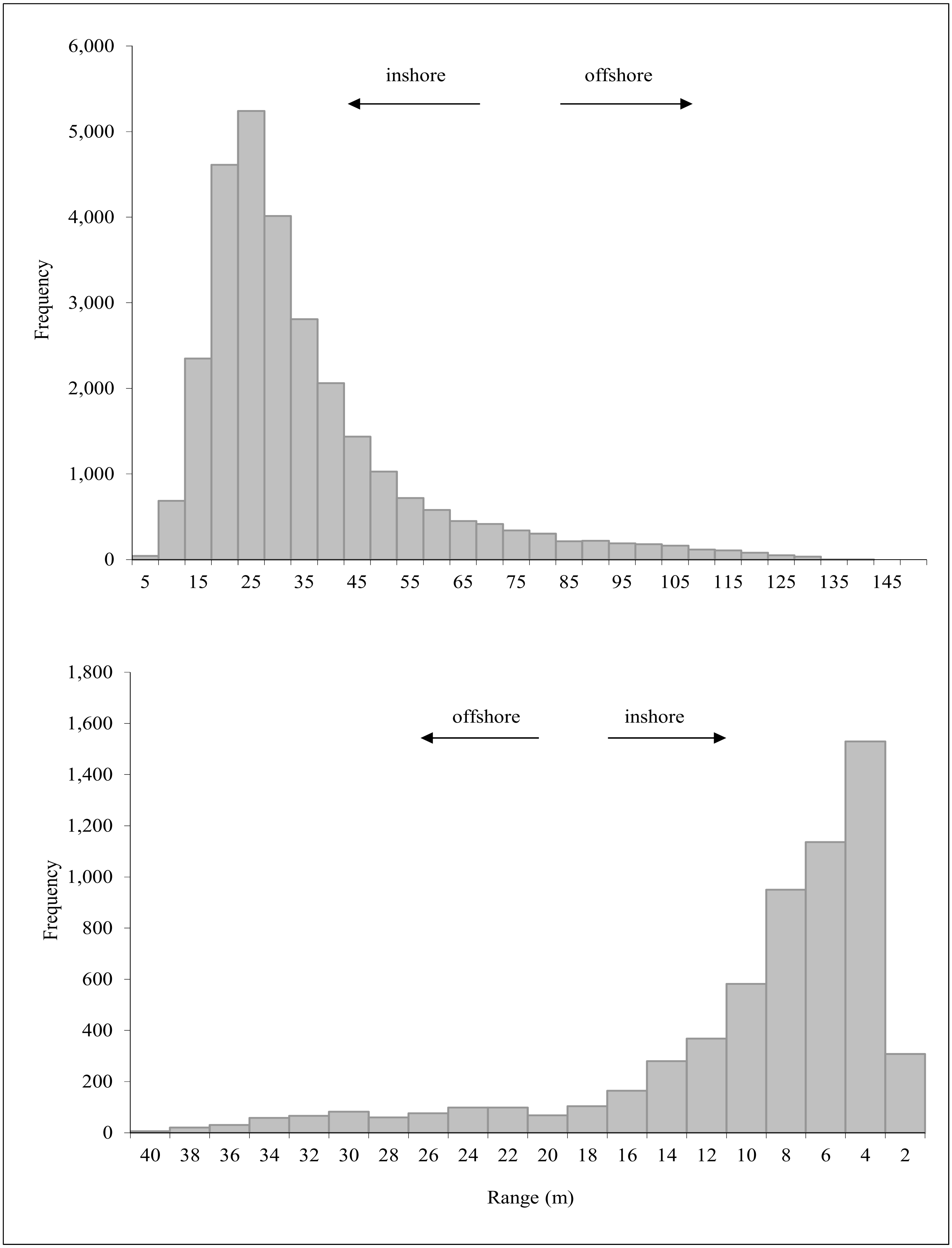

Figure 7.–Left bank (top) and right bank (bottom) horizontal distribution of upstream Chinook salmon passage in the Yukon River at Eagle sonar project site, July 4 through August 19, 2012.

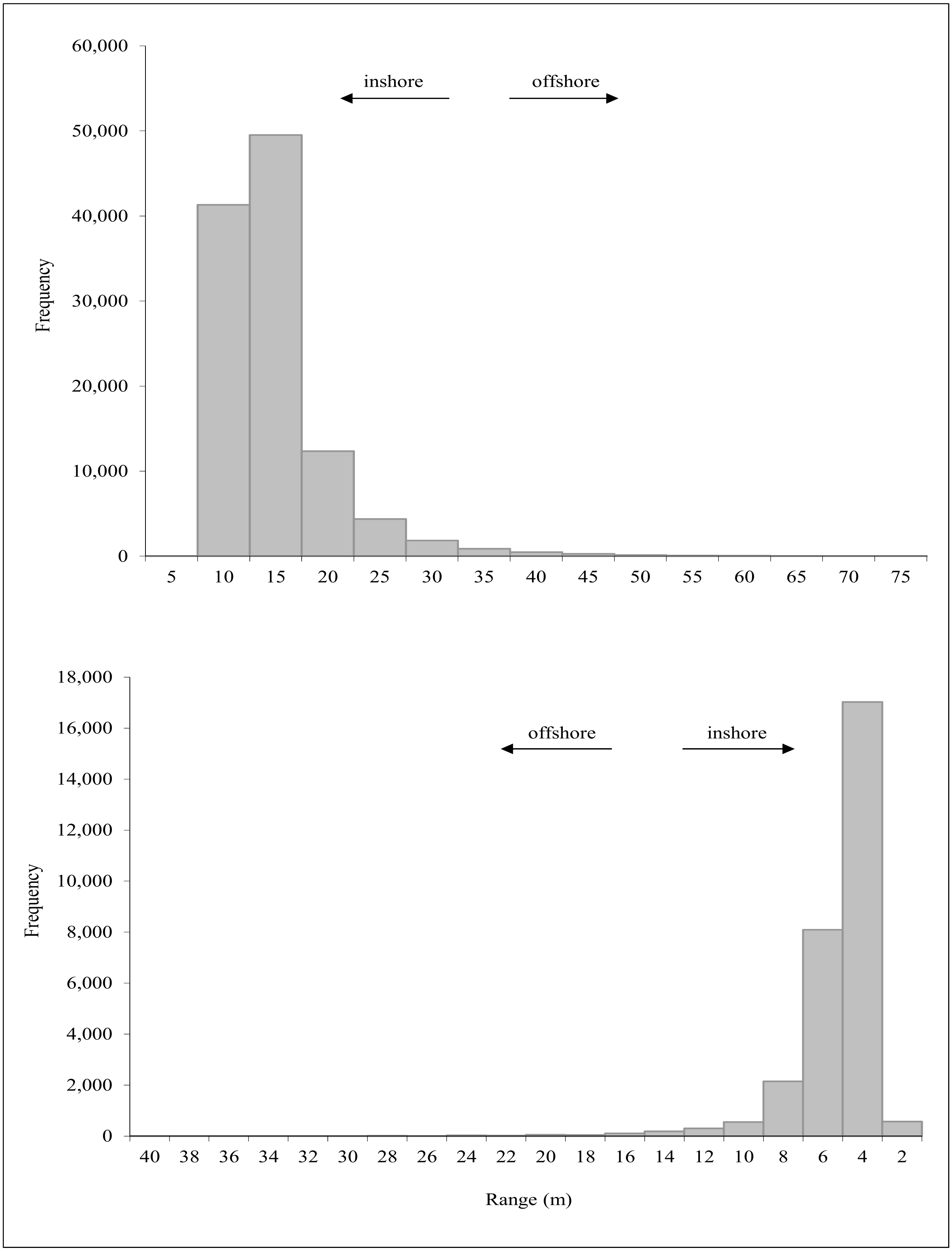

Figure 8.–Left bank (top) and right bank (bottom) horizontal distribution of upstream chum salmon passage in the Yukon River at Eagle sonar project site, August 20 through October 6, 2012.

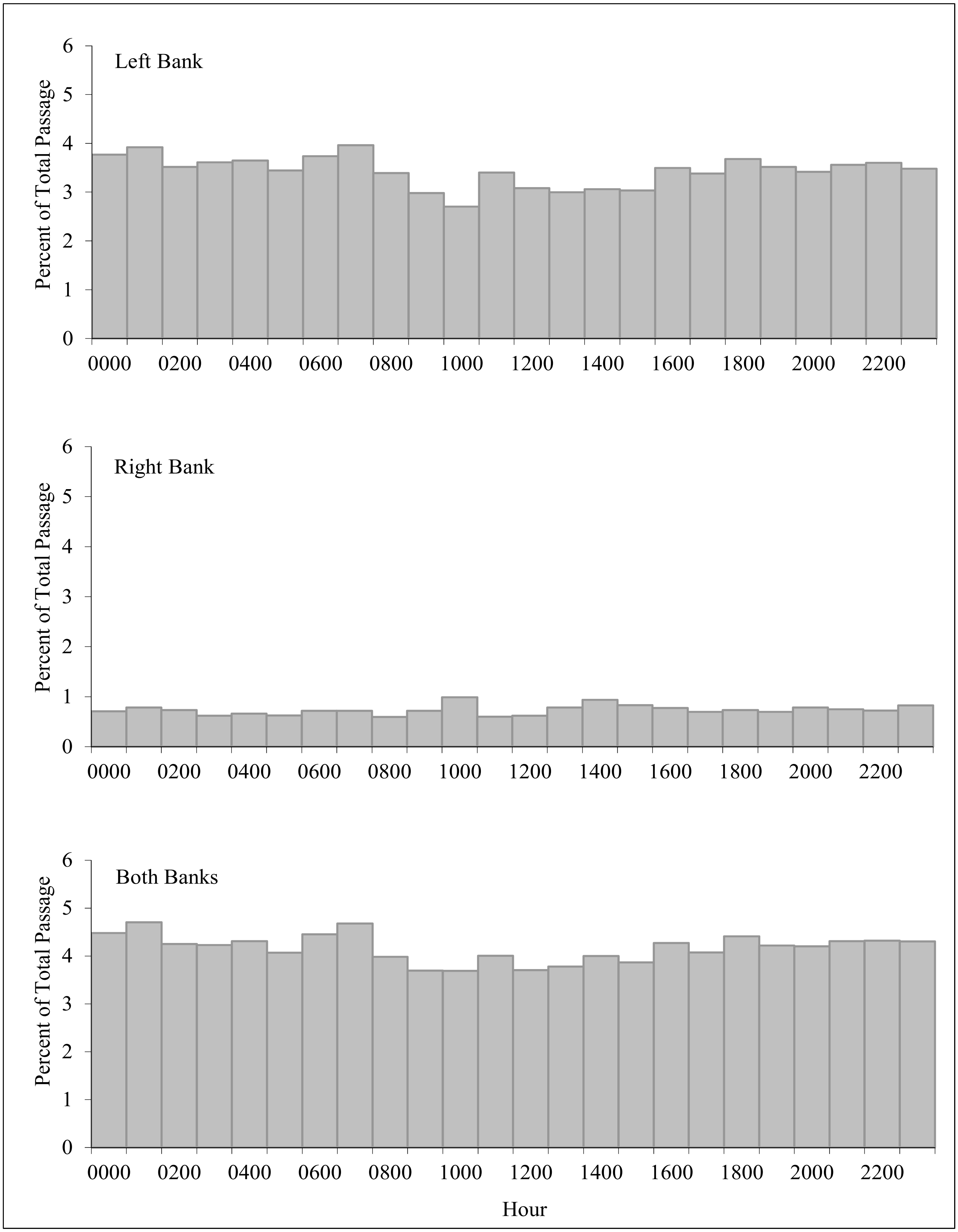

Figure 9.–Hourly Chinook salmon passage observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from July 6 through August 16, 2012.

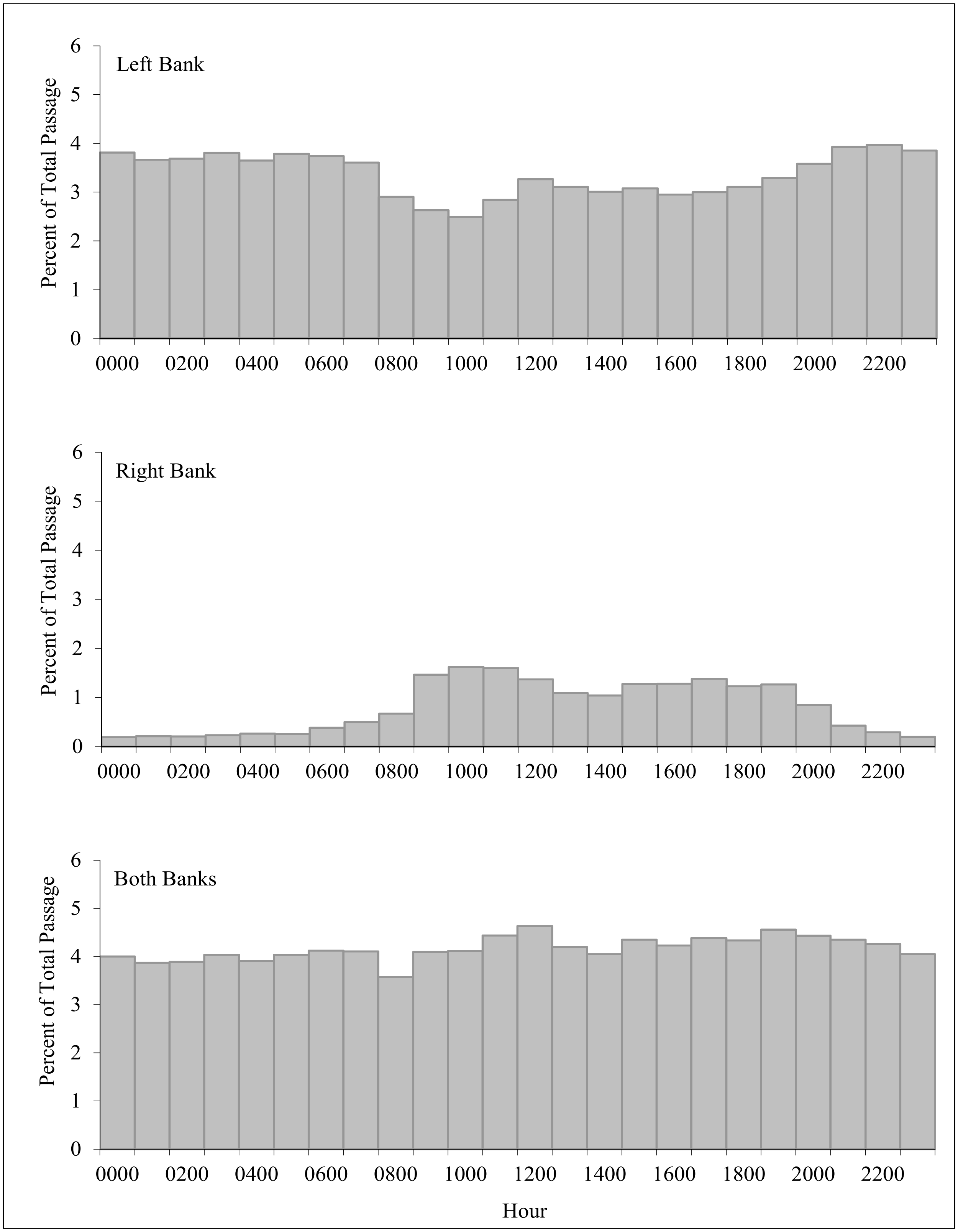

Figure 10.–Hourly chum salmon passage observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from August 20 through October 6, 2012.

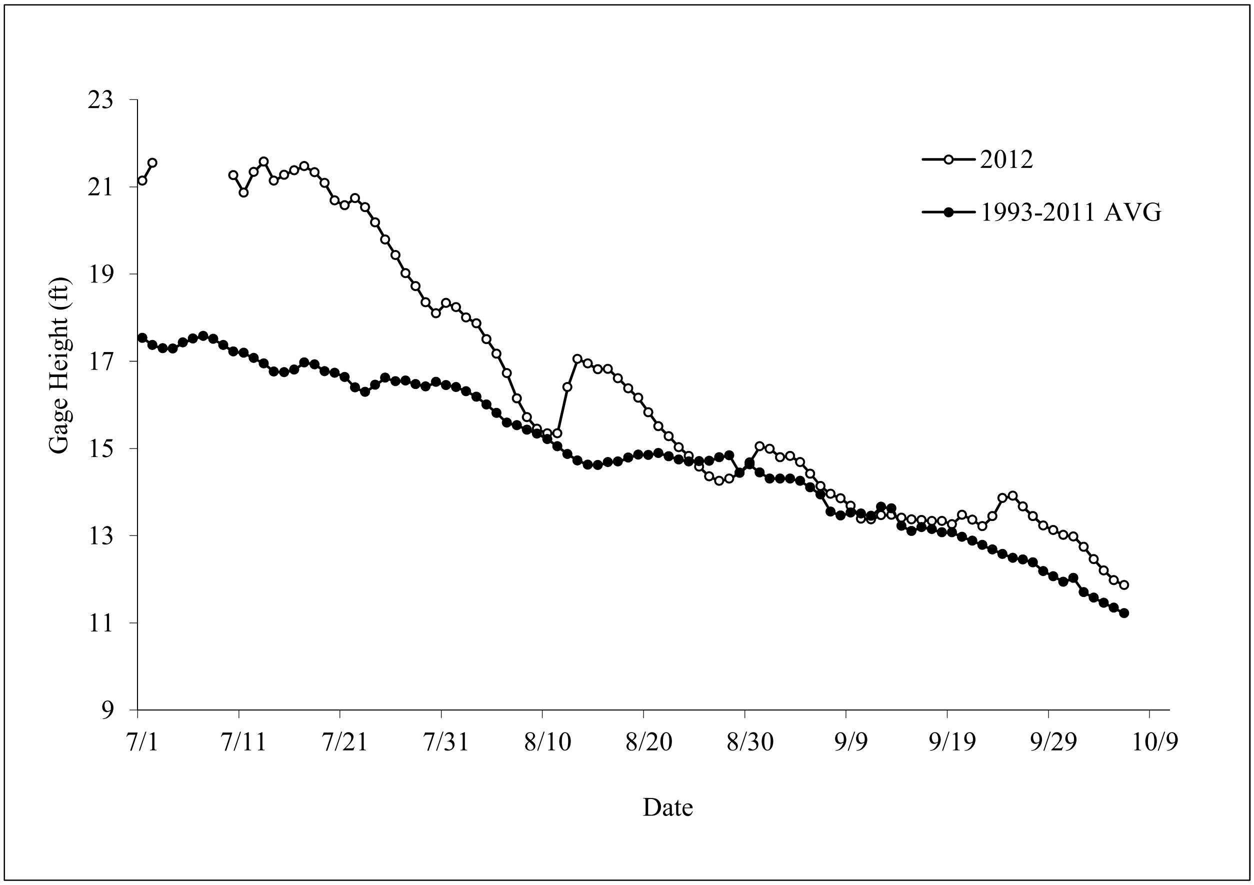

Figure 11.–Mean gage height measured at Eagle, July 1 through October 6, 2012, and historic mean 1993 through 2011.

Source: United States Geological Survey.

Note: Gage height data from July 3 through July 9, 2012 unavailable due to flood event.

APPENDIX A: CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climate and hydrologic observations recorded each day at 1800, Eagle sonar project site, 2012.

Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (C°) Air	Temperature (C°) Water[c]
7/5	B	N	3	B	20.0	14.0
7/6	A	S	6	C	24.0	13.0
7/7	B	variable	5	O	16.0	13.0
7/8	A	S	3	B	19.0	13.0
7/9	A	N	3	S	19.0	14.0
7/10	C	–	0	O	14.0	14.0
7/11	A	–	0	S	15.0	14.0
7/12	A	S	5	S	23.0	14.0
7/13	A	N	2	B	18.0	13.0
7/14	A	S	3	S	22.0	14.0
7/15	A	N	2	S	21.0	14.0
7/16	C	N	5	O	14.0	14.0
7/17	B	N	2	B	18.0	14.0
7/18	B	N	3	O	16.0	14.0
7/19	B	N	2	O	15.0	13.5
7/20	B	N	4	S	17.0	14.5
7/21	B	–	0	O	19.0	15.0
7/22	B	NE	2	B	19.0	15.0
7/23	B	N	1	B	20.0	15.5
7/24	B	S	3	S	20.0	16.0
7/25	A	E	3	C	19.0	16.0
7/26	A	SSW	8	C	27.0	17.0
7/27	A	N	6	C	27.0	17.5
7/28	A	NE	2	B	24.0	18.0
7/29	A	SW	6	C	25.0	18.0
7/30	A	SW	3	S	22.0	17.0
7/31	C	S	1	O	16.0	17.0
8/1	A	S	11	O	20.0	16.5
8/2	B	S	7	B	17.0	16.0
8/3	B	S	2	B	14.0	10.0
8/4	A	S	3	S	20.0	11.0
8/5	B	W	2	S	22.0	10.5
8/6	A	S	3	S	21.0	10.5
8/7	A	S	3	S	20.0	11.0
8/8	A	N	5	B	9.0	11.0
8/9	A	W	4	S	16.0	12.0
8/10	A	N	5	C	17.0	12.0
8/11	A	N	3	C	18.0	12.0
8/12	A	–	0	S	13.0	12.0
8/13	A	–	0	C	19.0	12.0
8/14	A	N	2	C	20.0	12.0
8/15	A	–	0	S	17.0	13.0
8/16	A	–	0	B	17.0	13.0
8/17	A	N	2	O	14.0	13.0

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Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (C°) Air	Temperature (C°) Water[c]
8/18	A	SW	4	C	17.0	14.0
8/19	B	SW	3	B	15.0	13.0
8/20	A	–	0	B	17.0	13.0
8/21	B	S	2	S	13.5	13.0
8/22	A	–	0	C	15.0	13.0
8/23	A	S	4	B	22.0	14.0
8/24	B	SW	3	B	18.0	13.0
8/25	B	–	0	S	13.0	13.0
8/26	B	SW	4	O	13.0	12.0
8/27	B	NE	5	O	10.0	12.0
8/28	B	N	5	B	10.5	11.0
8/29	A	N	2	O	11.0	11.0
8/30	B	SE	2	S	20.0	10.0
8/31	B	–	0	S	12.0	10.0
9/1	B	–	0	O	12.5	9.5
9/2	B	–	0	B	15.0	9.5
9/3	B	SE	1	O	13.0	9.5
9/4	A	S	6	O	17.0	9.5
9/5	A	S	1	S	19.0	10.0
9/6	B	S	3	S	11.0	9.0
9/7	A	N	2	B	10.5	9.0
9/8	A	N	3	B	9.0	9.0
9/9	A	N	1	O	8.5	6.0
9/10	B	N	2	O	5.0	6.0
9/11	A	S	2	B	9.0	6.0
9/12	A	–	0	B	13.0	6.0
9/13	A	S	4	S	11.0	6.0
9/14	A	–	0	O	14.0	6.0
9/15	A	S	10	O	14.0	6.0
9/16	A	S	10	B	18.0	6.0
9/17	A	S	3	S	14.0	6.0
9/18	A	S	10	B	12.0	6.0
9/19	A	S	9	B	13.0	6.0
9/20	A	–	0	B	14.0	7.0
9/21	A	–	0	C	13.0	7.0
9/22	A	S	5	B	18.0	7.0
9/23	B	S	8	B	14.0	7.0
9/24	A	–	0	C	8.0	8.0
9/25	A	S	4	B	11.0	7.0
9/26	B	S	5	S	11.5	7.0
9/27	B	–	0	B	8.0	7.0

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Appendix A1.–Page 3 of 3.

Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (C°) Air	Temperature (C°) Water[c]
9/28	B	S	2	O	10.0	6.0
9/29	A	–	0	B	4.0	5.5
9/30	B	N	4	O	1.5	4.0
10/1	B	–	0	B	0.5	4.0
10/2	A	S	7	B	4.0	4.0
10/3	A	S	4	S	5.0	4.0
10/4	A	S	4	O	7.0	3.0
10/5	B	S	2	O	10.0	3.0
10/6	B	–	0	O	8.0	3.0
Average					15.1	10.8

[a] Precipitation code for the preceding 24 h period: A = none; B = intermittent rain; C = continuous rain; D = snow and rain mixed; E = light snowfall; F = continuous snowfall; G = thunderstorm with or without precipitation.

[b] Instantaneous cloud cover code: C = clear, cloud cover < 10% of sky; S = cloud cover < 60% of sky; B = cloud cover 60–90% of sky; O = overcast (100%); F = fog, thick haze or smoke.

[c] Water temperature collected approximately 30 cm below surface with pocket thermometer.